Art. XVIII.—*The Geology of Coimaidai.*

Part II.

The Silurian and Glacial Beds.

By Graham Officer, B.Sc., and Evelyn G. Hogg, M.A.

With Appendices by C. W. De Vis, M.A., *and* T. S. Hall, M.A., *on the Marsupial Bones of the Coimaidai Limestone and the Graptolites of the District respectively.*

(With Plates VIII. and IX.).

[Read 11th November, 1897].

As stated in Part I. of the present paper a short account of the glacial beds of Coimaidai was communicated by us in conjunction with Mr. L. J. Balfour, B.A., to the A.A.A.S. at its Brisbane meeting in January, 1895. Since that time we have had opportunity for studying in detail the geology of the district, and though further acquaintance has led us to modify our opinions in minor details, it has on the whole confirmed the conclusions at which we had then arrived.

The Lower Silurian beds which form the base of the series exposed in the district consist mostly of sandstone, fine- and coarse-grained, slates and shales: they are highly inclined throughout the area and maintain a fairly constant strike of N. 10° E. The only fossils met with in the district are Graptolites, a description of which has been kindly communicated to us by Mr. T. S. Hall, M.A., for which see Appendix B.

In a section of the Silurian exposed in the Pyrete Creek, near Wightman's farm, a thin bed of conglomerate is intercalated between coarse grained sandstones; the included pebbles consist of well-rounded white quartz and the matrix is made up of quartz grains. The bed is lenticular in shape and rapidly thins out at either end; its length is about 20 feet, and its greatest thickness not more than eight inches; it is the only bed of its kind known to us in the district.

Permo-Carboniferous Glacial Beds. Under this name we have grouped a series of beds occurring in the district which are either of undoubted glacial origin or bear evidence that during their formation glacial conditions supervened. They are mainly developed in the western part of the district between the Goodman's Creek and Lerderderg River, many excellent sections being exposed in these streams; along the Pyrete and Back Creeks, and in the area north of Coimaidai drained by Basin Creek. In the absence of outcrops the nature of the subjacent glacial beds may be in many places plainly inferred from the profusion of striated boulders scattered over the surface of the ground.

In our division and nomenclature of the glacial beds we adhere to the plan adopted in our Brisbane paper, and classify them as follows:—

(1) Stratified mudstones.
(2) Glacial conglomerates.
(3) Stratified sandstones and freestones.

This terminology does not agree with that adopted by Professor David in his paper read before the Geological Society of London in February, 1896.[1] The beds which we call glacial conglomerates are apparently the same as his hard glacial mudstones; the beds he describes as conglomerates are so sparingly developed in the Coimaidai district as not to warrant a special division of the beds to include them. The beds which he calls clay-slates apparently correspond to our well stratified mudstones; we have observed no bed in our district to which the term slate can be properly applied.

Stratified mudstones. The beds are first described, as they form the lowest of the glacial series visible in our district. They consist of regularly stratified deposits of a more or less hard tenacious clay; they are occasionally finely laminated; they vary somewhat in colour, blue and yellow being the prevailing tints. Their glacial character is at once attested by the number of scored and scratched stones and boulders, varying from mere pebbles to huge rock-masses weighing tons, contained in them. The included stones and boulders are for the most part scattered irregularly through the matrix, but occasionally bands of these

---

[1] See Q.J.G.S., vol. lii., pt. ii., No. 206.

scored stones can be seen, as if they had been laid down on a level pavement, *e.g.*, sections near Elam's farm. The matrix is mainly argillaceous; it is usually fine-grained, but is in places from medium- to coarse-grained.

Glacial conglomerates. The second division of the glacial beds which we make we have, for want of a better term, called glacial conglomerates. These beds sometimes show an ill-defined stratification, but they very often appear to be quite unstratified. The matrix is very similar to that of the stratified mudstones, but the included scored stones are on the average somewhat smaller. The beds are usually of a purple colour where unweathered, and are extremely hard. The main difference between these beds and the mudstones is a question of stratification. It may here be mentioned that in both beds already described, irregular "nests" or patches of true conglomerate and coarse angular grit occur.

Stratified sandstones and freestones. These are well stratified beds forming the highest of the glacial series; they are developed only in the area between the Lerderderg River and Goodman's Creek, with the exception of a small outcrop on the E. of Goodman's Creek near its junction with Back Creek. They are quite similar in appearance to the Bacchus Marsh sandstones, and like them have been largely quarried for building purposes; they have yielded no fossil remains. They are often highly calcareous and sometimes contain magnesia. The frequent presence in these beds of erratics shows that the glacial conditions had not entirely passed away; it is worth noticing that these erratics are for the most part granite. They sometimes show current-bedding.

As the map of the district published herewith only shows the general distribution of the glacial series, it may be mentioned that the stratified mudstones are best exposed in the Goodman's Creek near and above Elam's farm, on the Lerderderg River, S.W. of this point, and on the Pyrete Creek, S. of the township of Coimaidai. The largest exposure of the conglomerate is in the S.W. part of our district, and of the sandstones at and south of the junction of Back and Goodman's Creeks, occupying the higher elevations.

Field observations. Starting at the S. end of Goodman's Creek, the glacial conglomerates extend northwards for several hundred yards. They present the usual characteristics of their class and show little or very indistinct traces of stratification. They merge upwards into sandstones and for a short distance dip in a north-easterly direction at a low angle. As we proceed further the dip fluctuates a good deal and at a point about a quarter-mile S. of Elam's farm it is apparently in a S.E. direction. This brings into view a series of beds, the lowest occuring in the district, which are exposed for about one and half miles up the creek. They are at first obscurely stratified: they consist of a blue coloured clay, and are less hard than the glacial conglomerates. Going further up the creek the stratification becomes more marked, and the beds become very rich in included boulders which are, generally speaking, much larger and more grooved here than elsewhere in the glacial series. Here occurs a small but well marked intercalated bed of boulders, which are much scored and show considerable uniformity in size and composition. A little beyond Elam's the beds have a slight dip to the N. Stratified mudstones continue up to the junction of the Back and Goodman's Creeks. At about quarter-mile below this junction a section is exposed about 140 feet in height; the beds composing it are somewhat scantily supplied with included boulders and stones. Here the mudstones pass upwards into the unstratified glacial conglomerates in which boulders are numerous though small; the conglomerates in turn pass upwards into sandstones, similar to the Bald Hill sandstones. This whole series dips a little E. of N. at an angle of from 10° to 20°. The sandstones cover a considerable part of this locality, a change of dip bringing the sandstone over to the E. bank of the creek at this point. North of the junction the Silurian rocks occur for the most part, but occasional patches of glacial beds may be seen.

The glacial beds are exposed along the Lerderderg River for about two miles above the point where the Goodman's Creek joins it. About a quarter of a mile above this point mudstones dipping to the S. and overlain by sandstones are seen, while at the big bend in the river a little further on sandstones and mudstones again occur. Beyond this blue well-stratified mudstones containing numerous scored boulders are encountered; they bear a strong resemblance to beds which occur on the Goodman's Creek, and they dip to the S. at about 10°. Mudstones are exposed on the opposite side of the river for a considerable distance, and finally at the sharp bend in the river close to the point at which it emerges from the ranges, an excellent section of the mudstone is exposed in a high bluff. This is apparently the section referred to by Daintree, and in our opinion the beds forming it are continuous with those composing the high bluff on Goodman's Creek previously referred to. Most of the area between the bluff on the Lerderderg River and the Back Creek is covered with glacial beds which are in places capped with tertiary formation.

On the Coimaidai side of the basaltic plateau glacial beds are exposed along the Pyrete Creek for a distance of about two miles southward from the township: they are mainly mudstones, some showing well-marked stratification, others little or none. Included boulders are numerous but somewhat small. No sandstones have been found in this part of the district. We are inclined to place the Pyrete beds on the same horizon as the upper mudstones of the Goodman's series. At the southern end of the Pyrete beds a considerable mass of glacial conglomerate occurs. The principal interest of the Pyrete beds lies in their association with the glaciated surfaces of the underlying Silurian rock, to which reference will presently be made.

Patches of glacial beds are found scattered over the broad valley drained by Basin Creek, to the N. of Coimaidai, but no good sections are exposed. Striated stone and foreign rock material are to be collected over a considerable area here.

Faults. At the N. end of the Goodman's Creek sections a good deal of faulting of limited extent has taken place. One of these we shall note as shown in section in one of the freestone quarries on the W. side of the creek. This has a throw of about 12 or 15 feet.

Another fault of greater importance occurs about half-way between here and Elam's farm. It is a compound fault, and is shown very distinctly, cutting through the lower mudstones of our series.

In this locality, owing to the softer nature of the lower stratified beds, a wide open alluvial flat stretches to the E. and across this flat, extending in an easterly direction, a more or less well marked ridge can be made out. This marks the course of the fault. The section exposed by the Creek shows the stratified mudstones to be suddenly interrupted by a mass of hard unstratified boulder-bearing mudstone, and about 20 yards or so in width. On the N. side it shows a very clean and decided wall at its junction with the stratified mudstones. On the S. side the junction is observed by recent alluvial and gravels, but doubtless the wall here is just as marked. It would appear that two parallel faults close together have occurred, and the mass between has been displaced. We are not in a position to state definitely whether this mass of rock moved downwards or upwards, but as the displaced bed corresponds very well in character to the second class of our division, we are much inclined to the opinion that it was a downward displacement, and probably does not amount to less than 50 feet. The harder material of the displaced mass has resisted weathering and denudation better than the softer stratified mudstones, and thus a ridge marks the course of the fault across the alluvial plain of the valley.

Dykes. A considerable number of dykes may be noticed penetrating the glacial beds exposed in the Goodman's Creek. Some are so decomposed that it is impossible to define their original character; those in a good state of preservation are composed of basalt, varying in structure from medium-grained to exceedingly close-grained. Several small ones occur in the vicinity of Elam's farm; close to the big fault just described there is a group of six or seven, while several small ones may be seen near the high bluff. They run more or less in an E. and W. direction, and are approximately parallel to the main joint planes which traverse the glacial beds in this locality. The occurrence of a bunch of dykes in close proximity to the fault alluded to above may indicate that the two phenomena are closely related. Similar dykes traverse the glacial beds exposed to the west on the Lerderderg River. We have nowhere observed a dyke passing through the over-lying tertiary beds, and it would thus appear that this system of dykes is not connected with the Bullengarook basalt which was poured out after the tertiary beds had been formed, but has arisen from some centre of igneous activity lying to the west of the district.

Rock material and erratics. The rock material found in the glacial beds is very abundant and of all kinds. Professor David in his Presidential address before A.A.A.S. remarks in his observations on the Korkuperrimul beds, that the bulk of the ground mass is of local origin, together with many of the boulders. Our observations, however, have led us to the conclusion that very few of the boulders are of local origin; some fragments of black slate quartz and quartzite may have been derived from local Silurian rocks, but the fact appears patent to us that the great bulk of the boulders is foreign. How far this is the case with the ground mass we hardly care to say, but we are inclined to think that a considerable portion of it is also foreign.

Another remark of Professor David's we are thoroughly in accord with, viz., the universal rounded and worn aspect of the boulders and pebbles, it being quite the exception to find an angular fragment.

A point to which we would also direct attention is that at certain horizons the boulders have a much greater average size than at others, besides being more numerous and more frequently and strongly glaciated. This can especially be observed in the sections of the blue mudstones on Goodman's Creek near Elam's farm. A section a little beyond Elam's shows a regular floor of boulders embedded in the mudstones. Just about here too occur the largest erratics we have found in the district. The following are particulars of a few of the best :—

(1) Hard sandstone, 6′ 6″ x 6′ x 3′ 6″.
(2) Quartzite, 4′ – 6″ x 4′ x 3′ – 6″.
(3) Granite, with large crystals of reddish felspar several inches in length, and well scored and grooved. Three years ago when we first discovered this erractic it measured 8′ – 3″ x 4′ – 5″ x 1′ – 10″. Mr. Elam informed us it was originally about 17 feet long.
(4) Granite similar to the last, and a little further down stream, about 10 feet in diameter.
(5) Hard blue quartzite, 8′ x 3′, partially exposed.
(6) Quartzite, 5′ x 4′ x 3′ – 6″.

Besides these many other boulders over 2 feet in diameter occur. One large fragment lying in the creek appears to have formed part of a glaciated surface, as the scored part is so well rounded, in contrast to the usual glaciated stone which is flattened where scored.

In the more unstratified mudstones the boulders and pebbles though numerous are as a rule small and well worn and show no trace of arrangement in the matrix, whereas in the stratified mudstones, as already remarked, a certain amount of arrangement is to be observed occasionally.

It is of importance to observe the more striking varieties of rock material among the boulders for the purpose of tracing their origin if possible. Many quartzites for example occurring in the drift would be difficult to trace to their source with any degree of certainty, but other kinds of rock may be of considerable value in this respect. Among such may be mentioned the various granites, gneiss, a felspar porphyry with a dark green ground mass containing red felspar crystals, certain quartz porphyries and a mica-diorite not unlike the Warburton trap rock. The granite most commonly met with is very coarse, some of the felspar crystals being several inches long. Besides the rocks above mentioned the included material consists of slate and quartz (probably derived from the local Silurian rocks) jasper, lydian-stone, greisen, conglomerate sandstone, grit and two blocks, one 18″ in diameter of marcasite, in a fine-grained quartzitic matrix. We have to thank Mr. Walcott, F.G.S., of the National Museum, for kindly examining this specimen.

During a visit to Springhurst, about two years ago, one of the authors observed several types of rock in the glacial drift there which we have not found in the Bacchus Marsh district. Among such may be mentioned a frequently occurring porphyry, with a slate-colored matrix, containing small crystals of quartz and a little felspar, a very red granite, and agatoid and jasperoid quartz. Boulders also of sandstone crammed with fossil casts of brachiopods, etc., are also frequent in this district. Mr. Etheridge, to whom one of these boulders was shown, said they might be Upper Silurian or Devonian.

We mention Springhurst in this connection as tending to show that certain kinds of rock may be confined more or less to a certain area, or indeed to certain horizons in the glacial series. And we would point out that the collection of the different kinds of rock material in the glacial beds with their position accurately marked, locally and in their proper horizon, would be a most valuable help in the unravelling of the glacial story.

Scored rock surfaces. One of the most striking features of the glacial geology of the district in the occurrence of scored rock surfaces and roches moutonnées. They are confined to the neighbourhood of the Pyrete Creek, and the exact positions of the better marked surfaces is indicated on the map. An exceedingly good example is seen on the Pyrete Creek about a mile below the bridge. The stream has here removed the glacial drift from the underlying hard Silurian sandstones, which now present the rounded and smooth appearance of typically glaciated rocks. These rocks, which extend for about 70 yards along the left bank of the stream, form two main masses, separated by an interval covered by alluvium, and for convenience in reference we have called them the "Pyrete Twins." In addition to the smoothed and rounded appearance may be noticed very distinct scorings and groovings, the general direction of which is from S.W. by W. to N.E. by E. Several hundred yards N.E. of the "Pyrete Twins" the Silurian again crops out at a higher level and exhibits a beautifully scored surface. There must have been at one time a considerable area of striated pavement exposed here, but unfortunately portions of it have been removed to furnish building stone for an adjacent cottage. The area remaining shows well marked grooves and striæ running in a S.W. to N.E. direction across a beautifully smoothed and polished surface. Both at this surface, which we have named "Wightman's Rock," and the "Pyrete Twins," the scorings correspond in direction neither with the strike nor the dip of the Silurian, but lie between the two. After very careful examination of these two instances we have no doubt that the glacier ice to which the scorings are due, came from the S.W. About a third of a mile further down the creek is a section showing the glacial conglomerate overlying the Silurian. The latter is again well scored and grooved, the direction being about N.E. In a small gully running parallel with the Melton Road, half a mile out of Coimaidai, another well scored surface can be seen, the direction of the groovings there being N. 35° E.

Numerous other examples occur in the district, but the above-mentioned are the best. Speaking in general, wherever the contact between the Silurian and the glacial beds can be seen, the former is scored and grooved in a manner that could only have been done in our opinion by a glacier or land ice-sheet moving from S.W. to N.E.

In several instances the direction of ice-flow is more easterly than this general course. In one case, in the valley of the Pyrete Creek, the scorings are about 75° E. of N. In another case, a scored surface occurring on the W. side of the Lerderderg, just outside the limit of our map, the direction is E. 10° N. We think it probable that the ice in the Coimaidai district travelled in a slightly more easterly direction than that in the Bacchus Marsh and Myrniong areas, owing to a certain local feature.

On looking at the accompanying map it will be seen that a little to the N. of Coimaidai, Silurian rocks outcrop in an E. and W. direction almost right across our area. At the time of glaciation this must have formed an escarpment or well marked ridge running transversely to the ice-flow, and probably causing a local deflection to the eastward.

Thickness and position of the Coimaidai series. The thickness of the glacial beds along the Goodman's Creek, shown in section along the line A B C of the accompanying map, is about 230 feet. Certain beds, however, outcrop on the Lerderderg River a short distance to the west of the mouth of Goodman's Creek, which probably lie above the ones shown in section, but owing to the manner in which the dip is masked by alluvium, we are unable as yet to prove the continuity of the beds and to determine their thickness. In any case we are inclined to regard the thickness given by us in our Brisbane paper as excessive.

Now, as the estimated thickness of the beds on the Korkuperrimul Creek is about 2000 feet, it is evident that we have only a portion of the series represented in the Coimaidai district, and it becomes a point of interest and importance to ascertain to what horizons in the larger section ours are to be relegated. We are, however, as yet unable to do this with any exactness.

The tripartite division of the glacial beds as indicated in our first paper on this district, is, as shown by Professor David, a notable feature of the Korkuperrimul Creek series, viz., stratified mudstones, unstratified mudstones or conglomerates, and sandstones. This association occurs again and again on the Korkuperrimul Creek. Gangamopteris occurs in sandstones at various horizons on the Korkuperrimul, but is most frequent in the uppermost sandstones at Bald Hill. So far we have not detected any fossils in our beds, and from this circumstance, and taking into account the dip and strike of the beds on the S. part of our area on the Lerderderg, we conclude that the Goodman's Creek series lie considerably below the Bald Hill sections, but are probably higher than the lowest on the Korkuperrimul.

Any theory of the conditions under which the glacial beds were formed has to satisfy two facts of prime importance, viz., the well-marked stratification of the mudstones and the foreign nature of the included material. Stratification is indeed not entirely absent from glacial deposits elsewhere exposed on the earth's surface, but it nowhere occurs either to the extent or perfection that it does in the beds of the Bacchus Marsh area. The large development of the stratified mudstones shows that in this district conditions prevailed during the glacial period which have been for the most part absent or entirely subsidiary in other glaciated areas. The theory which explains the formation of glacial beds elsewhere is inadequate here. As prime agents in the glaciation of the district we are limited to either icebergs or a land ice-sheet; either is a suitable vehicle for the transmission of material from one area to another; by means of either the presence of the foreign boulders in our beds may be explained, but in attempting to account for the stratification of the mudstones and the striation of the rock surfaces by means of icebergs grave difficulties present themselves; to these difficulties we have referred in the paper previously mentioned and do not propose to repeat them here.

In the present paper we ascribe the glaciation of the district mainly to a sheet of land ice which moved from the south; of the dimensions of this sheet but little can be said at present; it may have been and probably was continuous with the one to which we believe the glaciation of the Derrinal area is due, as the beds of this area bear a striking resemblance to those of the Bacchus Marsh area. The front of this ice-sheet terminated eventually in water; we are almost entirely in the dark as to whether this was marine or fresh; the little evidence furnished by the vegetable remains found in the Bacchus Marsh sandstones, and the total absence of any marine fossils point to a fresh-water lake. In this water were laid down the stratified mudstones and sandstones. We will first concern ourselves with the mudstones which form the lowest beds of the series in our district. From all glaciers terminating on the land sub-glacial streams issue, the water of these streams being derived from the melting of the glacier at its contact with the subjacent rocky bed, and at its upper surface exposed to the heat of the sun and atmosphere. That similar streams issue from a glacier whose front terminates in water there can be no doubt, as the same causes of melting are present in both cases. There has been but little opportunity afforded of studying the structure of beds formed from the sediment of sub-glacial streams discharging into a sea or lake, but reference will be made later on to the evidence brought to light in this matter at the Malaspina glacier. If a sub-glacial stream enter a sea or lake it will deposit the matter in suspension just as an ordinary stream does, that is to say, in stratified beds; this simple view of the matter does not account for the included stones in the mudstones. As stated before, we require that the glacier from which the sub-glacial streams issue should protrude into the lake or sea into which the streams empty. The existence of icebergs proves the possibility of a glacier advancing into the ocean, and the magnitude of icebergs shows that in cases the distance advanced through by the ice front before the berg is broken off is very considerable. Sir J. Ross records in his "Voyage of Discovery and Research in the Southern and Antartic Regions," that in many places the glaciers projected several miles into the sea. In investigating the physical relations of a glacier advancing into the sea, let us picture a mass of glacier ice, more or less loaded with included material, moving slowly down a moderate slope; the ice front would be pierced in places by the channels through which the sub-glacial streams issue; the lower part of the ice front would first reach the water, and would therefore be first subjected to melting by its contact with the water; as the forward movement continues the process of melting would result in the formation of an overhanging cliff of ice; any scouring action by the sub-glacial river would tend in the direction of wearing away the ice nearest to the bottom of the sea, and there would thus be a space more or less great according to circumstances between the lower side of the advanced ice and the bottom of the sea, and the sub-glacial streams would in consequence be unhindered in the distribution of their suspended matter. The disturbance and commotion which takes place when a berg is broken off and while it is seeking its position of equilibrium confirms the view just stated that between the ice-front and the sea bottom their exists a layer of water. In our view we must regard the sub-glacial streams as flowing for a longer or shorter period beneath the protruding ice-front; the matter held by them in suspension is being deposited in stratified beds beneath this tongue, which, as it slowly melts by its contact with the water, must drop the striated boulders, etc., it contains into the subjacent beds. If the ice-tongue continue to exist for a long time before the berg is broken off we should have a considerable profusion of included material in the beds beneath. With the separation of the berg mass from the parent tongue another set of conditions would arise; the formation of stratified beds by the sub-glacial streams would continue as before, but as the source of supply of striated stones, boulders, etc., has been removed by the floating away of the berg, the stratified beds should be almost entirely free from included matter, the only source of such material now being chance icebergs which might float over the site formerly occupied by the ice-tongue. In course of time the advance of a second tongue would lead to a repetition of the conditions favourable to the formation of stratified beds containing boulders, etc. In the sections along the Goodman's Creek we have both sets of beds displayed, the one rich in included material, the other destitute of it, but overlain by a second bed containing large quantities of boulders, etc. That a certain amount of the fine-grained material composing the stratified beds has melted out from the ice-tongue is probable; and though this would not interfere with the stratification of the beds, we are inclined to regard the sub-glacial streams as the principal agents in the formation of the stratified beds. It may also be pointed out that stratified beds with few included boulders might result during a climatic recession of the ice-front.

The evidence in regard to the formation of stratified glacial beds afforded by the Malaspina glacier is striking. This glacier, which is formed by the union of several ice-streams from Mount St. Elias, covers an area of 1500 square miles. In one place it comes down to the sea and terminates in cliffs sometimes 300 feet high. The lower part of the glacier is interrupted by two groups of hills, respectively named the Chaix and the Samovar Hills. They are described by Mr. J. C. Russell—who had charge of the exploration of the glacier in 1891—as "formed of a monoclinal block of conformable strata eight or ten miles long, trending N.E. and S.W., and tilted northward at an angle of 10 or 15 degrees. The general elevation of their crest is about 3000 feet. But what makes the hills especially interesting to the geologist is the fact that they are composed of stratified moranial material. The stratification is conspicuous even from a distance, but is due principally to slight differences of colour. Light purplish-brown alternating with light grey are the prevailing tints. The colours are in broad bands and may be traced continuously for thousands of feet. . . . . It is evident that the minimum thickness cannot be less than 4000 or 5000 feet. The rocks are essentially homogeneous from base to summit, and are composed of sandy clay containing large quantities of both angular and rounded boulders of all sizes up to 6 or 8 feet in diameter. The fact that they have been transported by glaciers is beyond question.

"In the finer portions of the deposit, especially in certain fine light grey sandy clays, sea shells are numerous. . . . . Besides the shells of molluscs there are shell cases of annelids (serpulæ?) attached to the glaciated boulders, showing that the stones on which they grew must have remained exposed at the bottom of the sea for some time before being wholly buried."

In the opinion of Mr. Russell, the Chaix and Samovar Hills were formed by the uplifting of the northern side of a fault or series of related faults.

Mr. Russell proceeds: "The interpretation of these various records leads to the conclusion that the strata composing the Chaix Hills were deposited about the extremity of a glacier which ended in the ocean. Portions of the finer material, especially that containing sea-shells, is largely glacial silt, while the boulders and gravel were deposited by the bergs that floated away from the face of the glacier. The deposit now forming at the extremity of the western lobe of the Malaspina glacier, where it breaks off into the sea, must be very similar to the strata forming these remarkable hills."

With this interpretation of the record we do not wholly agree; if the glacial silt was brought to the position it occupied prior to the uplifting of the beds by sub-glacial streams, it is not conceivable that the beds which were being formed from the sediments they carried should receive no boulders or gravel from the overlying stationary ice-sheet but only from those portions of the ice-front which had broken off and were presumably moving away from the area into which it is supposed they dropped the boulders, etc., they carried. The error has, we think, arisen from the assumption that a tongue of ice protruding into the sea is everywhere in contact with the sea-bottom beneath it, and this is an assumption that can only be upheld by showing that sub-glacial streams do not flow beneath a protruding tongue of ice and and is at variance with facts observed at the extremity of a glacier terminating on land. If the weight of the foremost parts of a land glacier can be sustained by the sides of the glacier valley and the columns of ice which separate the channels from which the ice-streams issue, it is entirely within the range of probability that when the glacier enters the sea and the force of buoyancy of the displaced water comes into play in the opposite direction to the weight of the mass that the advancing tongue will have contact with the sea-bottom only in places, and that there will exist channels which will permit of the flowing of the sub-glacial streams. These channels will change as the melting and scouring out of the ice continues, and this will permit of a wide and sometimes irregular distribution of the matter suspended in the streams and washed out of the ice. If the slope of the sea-bottom be sufficiently steep, the protruding ice-tongue may easily reach a point at which it requires no contact with the sea-bottom to support it, but is entirely upheld by the force of buoyancy arising from the displaced water; in this case there is no difficulty in accounting either for the stratification of the beds or the presence in them of included boulders.

There can be no doubt that the sandstones have been deposited in fairly deep calm water; false bedding is not entirely absent but in general uniformity of stratification is well maintained. The presence of erratics shows that the glacial conditions had not passed away, and that icebergs occasionally dropped their included material into the beds as they floated over. The general freedom of the beds from foreign matter, however, shows that either the icebergs were not very numerous or that they were but ill-supplied with included rocks and boulders. There is no evidence to show from what source the material composing the sandstones was derived ; any erratics they contain are similar in character to the boulders found elsewhere in the glacial beds.

The beds we have classed as conglomerates bear a general resemblance to the till or boulder clay of the glacial series of America and Europe ; and may represent the ground-moraine of the ice-sheet. The rude stratification they possess is very similar to that seen in certain of the glacial beds of America and Europe, but whilst the question of the origin of boulder clay or till is so contested a point among the glaciologists of Europe and America, we do not propose to enter into any detailed consideration of it. To each of the writers of the paper the appearance presented by the till of Great Britain is well known, and we are satisfied by observing that between the "till" and the beds classed by us as conglomerates, there is a strong general resemblance.

With regard to the formation of unstratified mudstones it may be pointed out that when a sub-glacial stream entered a lake where the separation of the ice from the bottom was very imperfect, the channel along which it flowed might speedily become gorged with sediment, forcing the stream to carve a new path through the ice. If the supply of sediment was great this might lead to the formation of beds showing little or no stratification ; but when the stream reached that position under the ice-front which would allow of the more gradual distribution of the sediment it carried stratification would begin to show. There would thus be a lateral passage or transition from unstratified to stratified beds—a feature often met with in the glacial series. There might also be a gradual transition from the true ground-moraine of the glacier into the sub-aqueous beds. Possibly the constriction of the channel occupied by the glacial stream may afford a clue to the explanation of the patches of water-worn gravel which, though present in the Coimaidai series, may be better observed in the Korkuperrimul Creek sections.

In conclusion it may be noticed that though the beds of the Coimaidai area show less complexity of structure than those exposed in the Korkuperrimul Creek, yet they must be regarded as part of the same series; similar general conditions probably prevailed over the whole Bacchus Marsh area, but in the country west of the Lerderderg River certain special conditions appear to have prevailed, the influence of which only partially, if at all, extended to the Coimaidai district. Their lacustrine origin under the action of an ice-sheet moving from the south is the feature common to all the beds, but the frequent occurrence on different horizon of boulder-beds separated by deposits of sandstone and conglomerate along the Korkuperrimul Creek points to a considerable variation of conditions during the gradual formation of the beds. The repetition of beds may be explained by climatic advances and recessions of the ice-front, and possibly in the area W. of the Lerderderg River there may have been considerable oscillations of level. Much evidence has been collected of late years to show that glaciers can move over loose and incoherent deposits without disturbing them, and Professor Geikie has ably argued that under certain conditions a glacier may cease to be erosive. Though a certain amount of contortion of the beds along the Korkuperrimul Creek has been noticed by Professor David, there is on the whole a striking absence of disturbance of the softer beds of the glacial series; an explanation of this feature may be found in the sub-aqueous formation of these beds.

EXPLANATION OF PLATES.

Plate VIII.

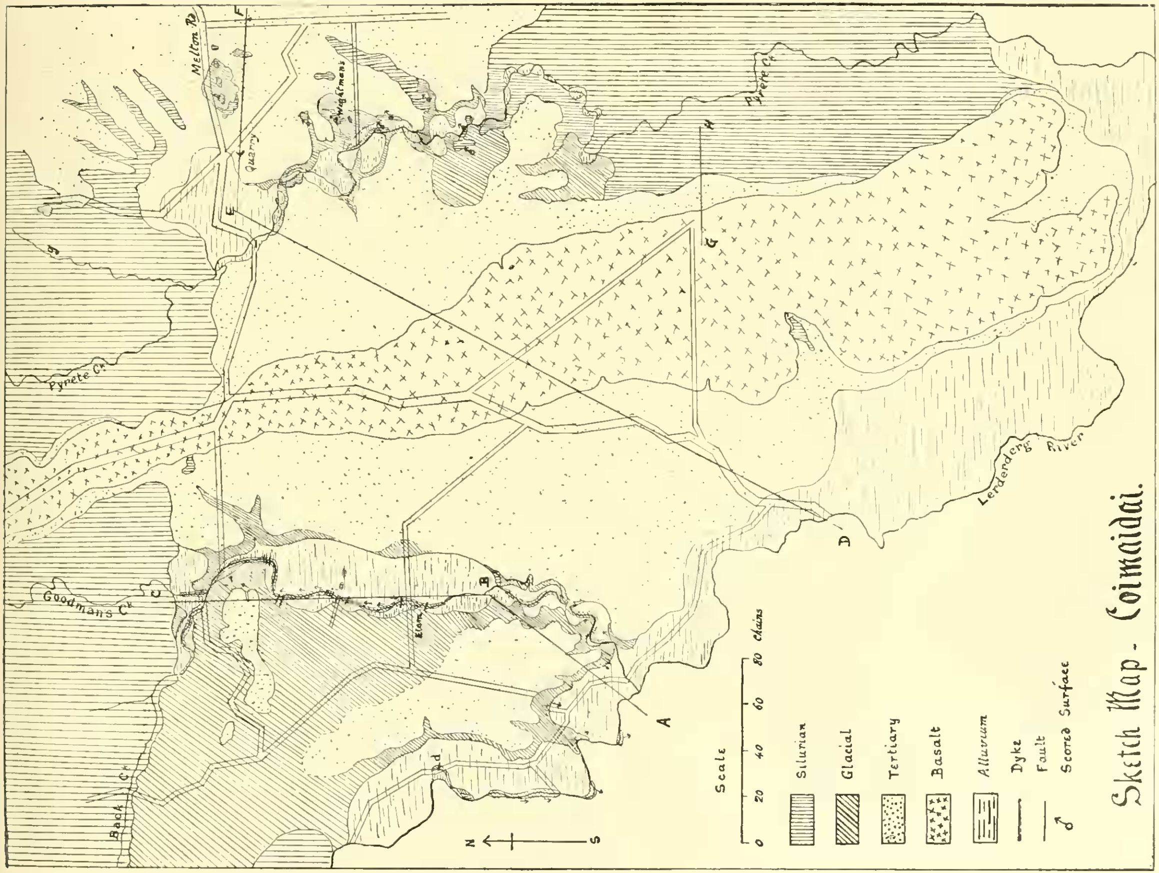
Sketch Map of Coimaidai.

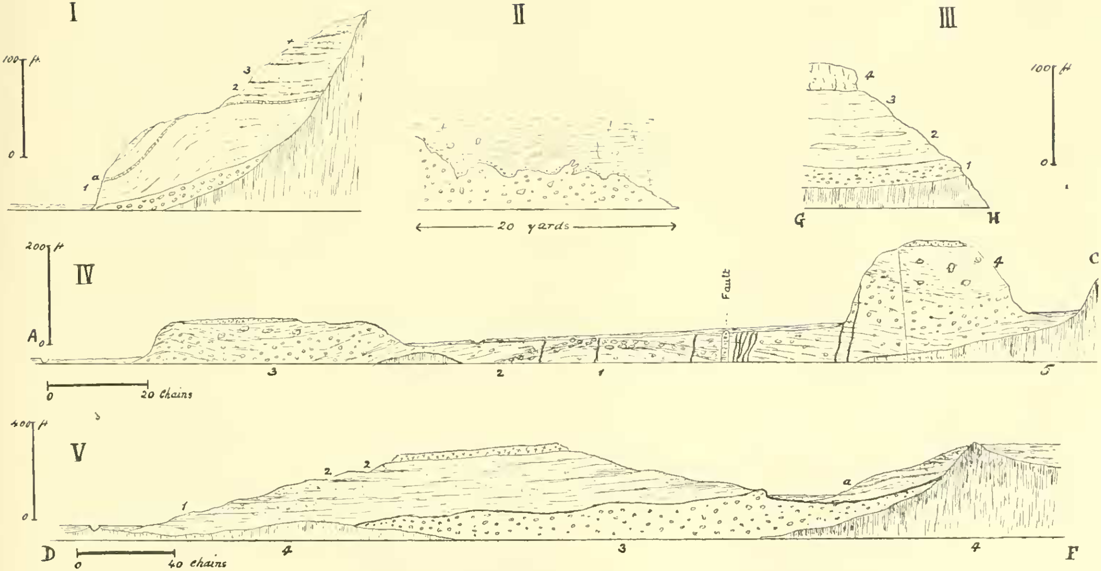
Plate IX.

I.—Section through tertiary beds near Alkemade's Quarry.

(1) Magnesian limestone, with partings of clay and gravel, and containing fossil marsupial bones.

(*a*) Thin band of volcanic ash, interstratified with (1). The fossil bones occur below this.


Sketch Map - Coimadai.
Scale
0
20
40
60
80 chains
Silurian
Glacial
Tertiary
Basalt
Alluvium
Dyke
Fault
Scored Surface
N
S
Lerderderg River
Goodmans Ck
Pyrete Ck
Back Ck
Melton Rd
Quarry
Elam
A
B
C
D
E
F
G
H


I
II
III
IV
V
100 ft
0
a
1
2
3
20 yards
G
H
4
200 ft
A
Fault
C
5
0
20 chains
400 ft
D
F
40 chains

(2) Sand and gravel.

(3) Quartzite.

(4) Gravel, sand and ferruginous conglomerate.

The whole rest on Silurian and Glacial.

II.—Section at junction of Goodman's and Back Creeks, showing uneven (eroded?) junction of sandstone with glacial mudstone. A thin line of angular pebbles occurs along the junction.

III.—Section along GH on map.

(1) Hard cemented conglomerate and quartzite.

(2) Sand and gravel, with clay and lenticles of limestone.

(3) Magnesian limestone containing casts of Limnæa, etc.

(4) Basalt.

The whole lies on Silurian.

IV.—Section along ABC on map, showing the Goodman's Creek series of Glacial beds.

(1) Well stratified mudstones, in which occurs.

(2) Zone of large numerous and well scored boulders.

(3) More or less unstratified beds (glacial conglomerates) passing upwards into

(4) Sandstones containing occasional erratics.

The whole is capped by tertiary gravels and conglomerates, and is intersected by numerous basalt dykes.

V.—Section along DEF.

(1) Thin bed of pipe clay containing leaf impressions (Laurus Werribeensis) and interstratified with sand and gravel.

(2) Thin beds or lenticles of magnesian limestone.

(*a*) Thin bed of volcanic ash interstratified with limestone containing Marsupial bones.

(3) Glacial beds.

(4) Silurian.

The whole capped by basalt 30–40 feet.

Appendix A.

On the Marsupial Bones of the Coimaidai Limestone.

By C. W. De Vis, M.A.

Of the twenty-two fossil bones and moulds more or less occupied by bone, collected by Messrs. Officer and Hogg, and by Mr. Ferguson, of the Mines Department, from Alkemade's Quarry, Coimaidai, about two-thirds are capable of determination; they are three lower jaws, seven pieces of long bones, four bones represented by cavities in the matrix, and one metatarsal. With the valuable exception of one jaw, these relics cannot be said to have been fossilized in a manner favourable to identification, and the difficulty of dealing with them is in most cases increased by their imperfect condition prior to burial. Without exception they are mammalian and marsupial. They have been contributed by three families of the Marsupialia, the Phascolomyidæ, Macropodidæ, and Nototheriidæ, and consequently are examples of the Nototherian fauna of Tertiary or Post-Tertiary time. To take them in order, the first to attract notice is a member of the

Phascolomyidæ. Phascolomys parvus, Ow.

The validity of this species is confirmed by the fossil under view, the horizontal ramus of a right mandible in a fine state of preservation, the teeth (save for the absence of the crown of the incisor) being in perfect condition. Apart from its rarity the mandible has a strong claim on our interest, as it unmistakeably correlates the Victorian beds with the drifts of Southern Queensland, and by showing how extensive was the range of this little Wombat, prepares us to expect similar diffusiveness in other Marsupials contemporary with it.

Macropodidæ. Halmaturus dryas, mihi.

Mandibles. A horizontal ramus of an adult left mandible. Of the premolar the fangs in their sockets are all the remains; the crowns of M^1 and M^2 are much corroded; the anterior talon in M^3

and the hinder lobe of M^4 are broken away; the remaining portions of the last two teeth have lost their enamel, and their whole substance indeed appears to have been converted into pseudomorphs of the originals and their surface characters obscured by calcareous matter, but their general form remains sufficiently evident to show by their straight sharp ridges that they could only have belonged to a Halmaturus. The dental series in this jaw measures by estimate 40mm., the sockets 52·5, and the anterior depth of the mandible is 29mm. In size, therefore, as in general facies, it agrees fairly with *H. dryas*, and to that species it is provisionally referred. The identification is supported by the presence of a second but left mandible from an aged individual; in this all the teeth of the molar series are in place, but like the last so fragile, that an attempt to remove encrusting matrix had to be abandoned. Enough of the imperfect premolar, however, is visible to show the size and form of the tooth. From these and from the length of the true molars little doubt remains as to its identification with the same species as the preceding jaw.

Femora. No entire skeletons of extinct Macropods have as yet been found or at least described. In the large collection of their remains accessible to me there are indeed but one or two instances of bones and teeth found together under circumstances suggestive of their specific co-identity. All the species but one being founded on jaws, the attributions of bones to certain species which have been hitherto or are still made by authors, are therefore conjectural and at the best approximative. But since measurement enables us to refer every recognisable bone provisionally to one or two or three species, we may fairly allow our choice so limited to be guided by the extraneous conditions of the case. It should at the same time be remembered that identification by measurement proceeds on the assumption that the proportions of the animal in question were the same as those found in the living species taken as a base of comparison, an assumption which under the circumstances cannot be verified. Under the impression, however, that it is better to get as near as possible to accuracy, in spite of uncertainty, than to neglect enquiry because of uncertainty, I venture to attribute to this species the bones which seem to pertain to it. Among these are